# POPULATION SYNTHESIS AND SUPERNOVAE

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**ABSTRACT.**
On the basis of a set of population synthesis models of simple stellar populations, we discuss the variation induced by SN explosion on the emitted light of stellar systems. We find that observable modifications in the integrated magnitudes and colors are foreseen by our models. We provide the expected photometric variations in different filters ($U, B, V, R, I, J, H, K$) which should be observed in case of SN events in galaxies located at redshift values ranging from 0 to 6.

## 1. Introduction

Modern population synthesis codes usually take into account most of the stellar evolutionary phases like MS, SGB, RGB, HB, AGB, post-AGB and WD. To include also the quoted fast but luminous evolutionary phases becomes necessary if one is interested in studing the integrated light of stellar systems populated by a large number of stars as in the case of galaxies.

A further extension of such investigation is to understand how a *very fast*, but *very luminous*, 'evolutionary phase' like a SN event may modify the integrated properties of a distant galaxy. The quantities involved are quite extreme: the timescale is of the order of few days and the absolute magnitude is about $M_V \simeq -19$.

At this point a number of questions can be done from the point of view of the population synthesis:

1. Does the SN event change the integrated magnitudes and colors of a galaxy? How much?
2. Does the variation of the integrated magnitudes and colors depend on the galaxy evolutionary state and/or on the chemical composition of the dominant stellar population?
3. How these variations change as a function of the galaxy redshift?
4. What are the expected apparent magnitudes of a galaxy + SN at high redshift ?

In this paper we try to give answers but also to arise some provocative question on this topic.

## 2. The population synthesis models

The models presented here are widely described in Brocato et al. (1999) and for this reason we just summarize here the main assumptions:

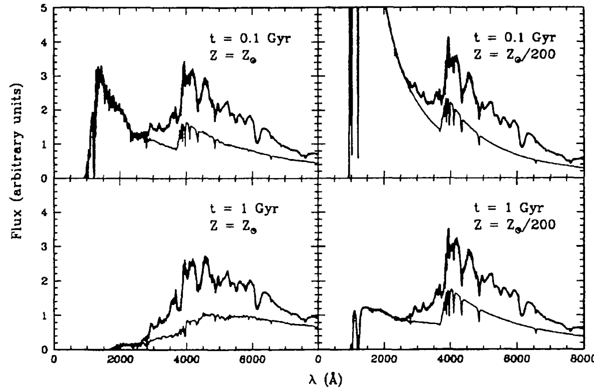


Fig. 1. Spectral Energy Distribution for 4 different galaxy models (thin lines). Thick lines are the composite spectra (galaxy plus SNIa). $M_V^{gal} = M_V^{SNIa}(max) = -19$ is assumed.

- We adopt an homogeneous set of stellar evolutionary tracks of high (Brocato & Castellani 1993) intermediate (Cassisi et al. 1994) and low mass (Straniero & Chieffi 1991, Castellani et al. 1992) stars.
- All the population synthesis models rest on the assumption that all the stars have the same age and the same chemical composition (simple stellar population).
- The adopted IMF follows the Salpeter power law and the stellar spectra come from Kurucz (1995) models.

In this work we use population synthesis models representing galaxies having ages and metallicities as listed in Table 1. All the galaxy models are normalized to have $M_V^{Gal} = -19$, otherwise it will be indicated.

**Tab. 1 - Age and metallicity of the population synthesis models**

| age (Gyr) | metallicity |
|---|---|
| 0.03 | $Z_\odot$ |
| 0.1 | $Z_\odot$ |
| 0.1 | $Z_\odot/200$ |
| 1.0 | $Z_\odot$ |
| 1.0 | $Z_\odot/200$ |

On the other side, the Supernova event is simulated for two different type: SN Ia and SN II. The SN Ia is modelled by using the SN 1992A observed spectrum ranging from the UV to the near IR. The adopted absolute magnitude is $M_V^{SNIa}(max) = -19$ ($H_o = 75$ Km s$^{-1}$ Mpc$^{-1}$). For SN II we adopt a blackbody (T = 25000 K) normalized to obtain $M_V^{SNII}(max) = -15.3$ (which means L= $3{\cdot}10^{42}$ erg s$^{-1}$).

## 3. The effect of SN explosions on the integrated light of a galaxy

To evaluate the expected variation of the integrated magnitudes and colors of a galaxy, we simply add the SN spectrum to the SED of our galaxy models (see Fig. 1 for the SN Ia and Fig. 3 for SN II) and then the flux in each photometric band is calculated. The flux ratio obtained for the $UBVRIJHK$ bands in the case of SN Ia is presented in Table 2.

**Tab. 2 - Expected flux ratios ($\frac{F_{gal+SNIa}}{F_{gal}}$) in various photometric bands.**

| $\frac{F_{gal+SNIa}}{F_{gal}}$ | $t = 0.1$ Gyr $Z_\odot$ | $t = 0.1$ Gyr $Z_\odot/200$ | $t = 1$ Gyr $Z_\odot$ | $t = 1$ Gyr $Z_\odot/200$ |
|---|---|---|---|---|
| $U$ | 1.83 | 1.50 | 3.00 | 1.87 |
| $B$ | 1.96 | 1.74 | 2.47 | 1.88 |
| $V$ | 2.00 | 2.00 | 2.00 | 2.00 |
| $R$ | 1.80 | 1.97 | 1.66 | 1.84 |
| $I$ | 1.45 | 1.66 | 1.33 | 1.50 |
| $J$ | 1.14 | 1.31 | 1.09 | 1.20 |
| $H$ | 1.06 | 1.18 | 1.04 | 1.11 |
| $K$ | 1.04 | 1.12 | 1.02 | 1.07 |

We also investigate what happens if the absolute magnitude of the host galaxy increases from our reference value $M_V^{Gal} = -19$ to $M_V^{Gal} = -20$ or $M_V^{Gal} = -21$. Fig. 2 shows the behaviour of the expected magnitude variations ($\Delta$ Mag) due to a SN Ia for different assumptions on $M_V^{Gal}$.

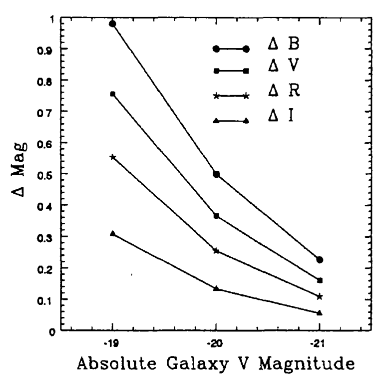


Fig. 2. Photometric variations expected as function of the absolute magnitude of the parent galaxy.

In the case of SN II, one can see in Fig. 3 that a single SN II event does not change in a sizeable way the SED of a galaxy where a dominant "young" stellar population is present. For example the variation in the V band is smaller than 0.2%. To obtain integrated V magnitude variations of the order of 0.5 mag in a galaxy model with

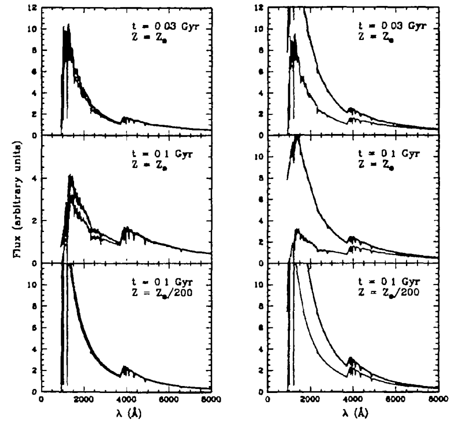


Fig. 3. *Left panels:* The expected SED for three labelled galaxy models (thin lines) are compared with the composite spectrum where the flux of a single SN II is added (galaxy plus SN II). *Right panels:* as in the left panels but the contribution of 10 SN II events is simulated.

$M_V^{Gal} = -19$ we find that at least 10 *simultaneous* SN II are required (which clearly implies an unrealistic SN rate).

## 4. Variability due to SN Ia in high redshift galaxies

Let us now focus the attention on the photometric variability due to SN Ia events in high redshift galaxies. We redshift the galaxy and SN spectral energy distributions at a given value of $z$ (intergalactic absorption by Madau 1995). After adding the two spectra we derive the expected flux in the photometric bands providing value which represent directly the observed magnitudes and colors. To present these results, we plot the expected variations in the integrated magnitudes and colors (Fig. 4) in a selected sample of photometric filters.

The main results can summarized as follow:

- For redshift z > 1 the variation of the galaxy magnitude due to the SN Ia explosion becomes negligible in B and V bands.
- In the K band, the variation of the magnitude is of the order of 0.5 mag or larger for $2 < z < 6$.
- The galaxy model with $Z = Z_\odot$ and t = 1 Gyr has a peculiar behaviour due to its particular galaxy SED, in the sense that it has a low 'blue' flux and a low 4000 Åbreak. This behaviour remains at high redshift.
- A valuable color indeces variability is found, being the $\Delta(B-V)$ of the order of 0.4 mag at $z \simeq 0.5$ and $\Delta(V-I)$ of the order of 0.6 mag at $z \simeq 1$. For larger redshift values we find that $(I-K)$ and $(J-K)$ show variations larger than 0.6 mag when $z$ is larger than 2.

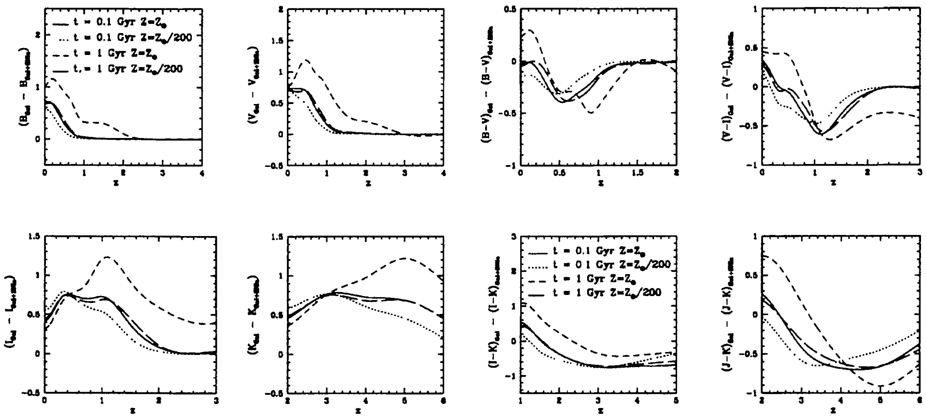


Fig. 4. Selected magnitude (*left panels*) and colors (*right panels*) variations for four galaxy models plus the SNIa as a function of redshift. The reference values $M_V^{gal} = M_V^{SNIa}(max) = -19$ are assumed.

Finally, we present the expected integrated apparent magnitudes of a galaxy model (t = 1 Gyr and Z = Z$_\odot$) hosting a SN Ia as function of redshift $z$ (Fig. 5b) and the apparent magnitudes of a SN Ia again as function of the redshift (Fig. 5a).

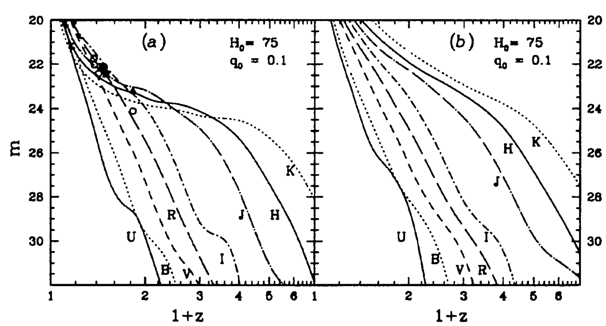


Fig. 5. *(a)*: $UBVRIJHK$ apparent magnitudes as a function of redshift expected by a SNIa event assuming the labelled cosmological parameters $H_o$ (in km s$^{-1}$ Mpc$^{-1}$) and $q_o$; *(b)*: as in panel (*a*) respectively but the contribution by the SED of a galaxy model of age $t = 1$ Gyr and metallicity $Z = Z_\odot$ is added. The apparent $R$ (open circles) and $I$ (filled triangles) magnitudes of a sample of observed SNIa are plotted.

## 5. Conclusion

We compute the photometric variations in the $UBVRIJHK$ bands expected from a galaxy in case of a SN event, considering the galaxy redshift ranging from 0 up to 6.

In the case of SN Ia the size of these photometric variations can be larger than 0.5

mag depending on the selected filters and the galaxy redshift. Furthermore, the age and the chemical composition of the galaxy may affect the amplitude of this variability but it remains largely detectable.

As a final remark, let us note that next generation telescopes will require a large creative effort in developing scientific research which fully takes into account all their tremendous observational capabilities. In this scenario supernova surveys will certainly play a prominent role. The present theoretical evaluation are also intend to be a way to look at SN search from an alternative point of view. In this sense, can these integrated variation be useful in identifing SNe in distant galaxies ? The point of view of population synthesis can help in determinig new observational strategies?

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